Last Time

MODEL

ASSUME

1V < V_{20}

V_{20} => HALF WAVE RECTIFIER

\[ V_0 = V_0 \sin(\omega t) \quad \text{where} \quad \omega = 2\pi f = \frac{\pi}{T} \]

\[ \langle V_s \rangle = 0 \]

\[ \langle V_L \rangle \neq 0 \]
LAST TIME: HALF WAVE RECTIFIER WITH FILTER CAP.

\[ V_s = V_0 \sin(\omega t) \]

\[ V_L \approx \left[ V_0 - V_{do} \right], \text{i.e. DC with ripple} \]
\[ V_r \approx (V_0 - V_{do}) \cdot \frac{T}{\tau} ; \tau = R_L C \]
\[ I_L \approx \frac{V_0 - V_{do}}{R_L} ; \quad I_D^{\text{peak}} \approx \frac{V_0 - V_{do}}{R_L} \left( 1 + \frac{2(V_0 - V_{do})}{V_r} \right) \]

PEAK INVERSE VOLTAGE \rightarrow \text{MAX RB DIODE TAKES.}

IN THIS CIRCUIT \hspace{1cm} PIV = V_0 \hspace{1cm} \text{AMPLITUDE OF INPUT SINE WAVE}

\( \otimes \) NEED \hspace{1cm} PIV < V_{20} \hspace{1cm} \text{CLEARLY}
Full Wave Bridge Rectifier

1. $V_s > 0$
   - $V_L = V_s - 2V_{DO}$
   - $V_o = 2V_{DO}$

2. $V_s < 0$
   - $V_L = V_s - 2V_{DO}$

$V_s = V_0 \sin(\omega t)$

Both half waves are utilized but price is $2 \cdot V_{DO}$!
P.I.V of Bridge Rectifier

\[ V_D = P.I.V = V_0 - 2V_{DO} - (-V_{DO}) = [V_0 - V_{DO}] \]

P.I.V < V_{ZO}
BRIDGE RECTIFIER WITH CAP

\[ T = R \cdot C \]

\[ \Rightarrow V_r \approx [V_o - 2V_{do}] - [V_o - 2V_{do}](1 - \frac{T/2}{T}) = \]
\[ = \frac{[V_o - 2V_{do}]}{2} \cdot \frac{T}{T} \]

i.e. twice smaller than in half wave case!
PEAK DIODE CURRENT

\[ V_r = \left[ V_o - 2V_{do} \right] \cdot \frac{I}{2\pi} \]

\[ \Delta t = \frac{T}{2\pi} \sqrt{\frac{2V_r}{\left[ V_o - 2V_{do} \right]}} \]

\[ \Delta Q = C \cdot V_r \Rightarrow I_{\text{charge of cap}} \approx \frac{\Delta Q}{\Delta t} = \frac{CV_r}{\frac{T}{2\pi} \sqrt{\frac{2V_r}{\left( V_o - 2V_{do} \right)}}} \]

\[ = \frac{2\pi C}{T} \sqrt{\frac{V_{\text{max}} - V_r}{2}} \sim C \cdot \sqrt{V_r} \]
Observe no ground at bridge rect. input

We use transformers

\[
\frac{V_S}{V_{AC}} = \frac{N_2}{N_1}
\]
TOROIDAL SOLENOID

INDUCTANCE
\[ L = \frac{\Phi}{I} \]
MAGNETIC FLUX CREATED BY I
\[ \sum I \rightarrow N \]
HERE: \( \Phi = B \cdot A \cdot N \)
\[ [\Phi] = W \]
B - MAGNETIC FLUX DENSITY
A \cdot N - TOTAL AREA

\( N \) - NUMBER OF TURNS

\[ A \cdot \text{CROSS SECTION AREA} \]
\( \mu_r \gg 1 \)

\( \square \) AMPERE'S LAW

\[ \oint_B \vec{B} \cdot d\vec{l} = \mu_r \cdot \mu_0 \cdot I \]
\( \mu_0 = 4\pi \cdot 10^{-7} \cdot \frac{N}{M} \)
\[ [B] = \frac{W}{M^2} \]

\( \square \) FARADAY'S LAW OF INDUCTION
\[ V_L = L \frac{dI}{dt} \]
CORE WITH TWO COILS

\[ \begin{align*}
I_1 & \text{ produces } \Phi_1 \\
I_2 & \text{ produces } \Phi_2 \\
L_1 &= \frac{\Phi_1}{I_1} \propto N_1^2 \cdot \mu_r \\
L_2 &= \frac{\Phi_2}{I_2} \propto N_2^2 \cdot \mu_r
\end{align*} \]

SELF INDUCTANCE

MUTUAL INDUCTANCE

MAGNETIC FLUX CREATED BY \( I_1 \) WILL CUT THROUGH COIL 2

\[ \frac{\Phi_2}{I_1} \text{ & } \frac{\Phi_1}{I_2} \text{ - ?} \]

\[ \frac{\Phi_2}{I_1} = \frac{(N_2A) \cdot B_1}{I_1} = M \propto N_1 \cdot N_2 \cdot \mu_r \]

\[ \frac{\Phi_1}{I_2} = M \text{, where } M = \sqrt{L_1 \cdot L_2} \]

IDEAL CASE, I.E.: NO LOSS OF B!
**IDEAL TRANSFORMER**

\[ V_1 = j\omega L_1 I_1 + j\omega M I_2 \]  
\[ V_2 = j\omega L_2 I_2 + j\omega M I_1 \]

\[ V_1, V_2, I_1 \text{ and } I_2 \text{ — phasors} \]

\[ I_1 = \frac{V_2}{j\omega M} - \frac{L_2}{M} I_2 \rightarrow \text{to (1)} \]

\[ V_1 = \frac{L_1}{M} V_2 - j\omega I_2 \left[ \frac{L_1 L_2}{M} - M \right] \]

\[ K = \frac{M}{\sqrt{L_1 L_2}} \text{ — COUPLING COEFFICIENT} \]

IDEAL CASE $\Rightarrow K = 1$ ($M = \sqrt{L_1 L_2}$)

$\Rightarrow V_1 = \frac{L_1}{M} V_2 = \sqrt{\frac{L_1}{L_2}} V_2 = \sqrt{\frac{N_1^2}{N_2^2}} \cdot V_2 = \frac{N_1}{N_2} V_2$

\[ \frac{V_2}{V_1} = \frac{N_2}{N_1} = n \text{ — RATIO OF NUMBER OF Turns} ! \]
**What about currents**

\[
I_1 = \frac{V_2}{j\omega M} - \frac{L_2}{M} I_2 = \frac{V_2}{j\omega M} - \sqrt{\frac{L_2}{L_1}} I_2 = \frac{V_2}{j\omega M} - n \cdot I_2
\]

\[
\frac{V_2}{j\omega M} = \frac{V_2}{j\omega \sqrt{L_1 L_2}} = \frac{V_1 \sqrt{L_2/L_1}}{j\omega \sqrt{L_1 L_2}} = \frac{V_1}{j\omega L_1} \rightarrow 0
\]

**Then:** \[I_2 / I_1 = -n\]

**Power delivery**

\[
\frac{P_2}{P_1} = \frac{V_2(-I_2)}{V_1 I_1} = n \cdot (-1) \left(\frac{-1}{n}\right) = 1 \quad \text{for ideal}
\]
Power delivery from source to load.

\[ P_{S}^{\text{MAX}} = \frac{V_s^2}{R_s} \]
when \( R_L \) - shorted

\[ P_L = I_L \cdot V_L = \frac{V_s}{(R_s+R_L)} \cdot \frac{V_s}{(R_s+R_L)} \cdot R_L \]

\[ P_{L}^{\text{MAX}} \text{ when } R_L = R_s \]

\[ P_{L}^{\text{MAX}} = \frac{1}{4} P_{S}^{\text{MAX}} = \frac{V_s^2}{4R_s} \]

What if \( R_L \neq R_s \Rightarrow P_L < P_{L}^{\text{MAX}} \)
**IMPEDANCE MATCHING USING TRANSFORMER**

\[
Z = \frac{V_1}{I_1}; \quad \frac{V_2}{V_1} = \frac{N_2}{N_1} \quad \& \quad \frac{I_2}{I_1} = -\frac{N_1}{N_2}
\]

\[
Z = \frac{V_1}{I_1} = V_2 \frac{N_1}{N_2} \cdot \frac{1}{I_2 \left(-\frac{N_2}{N_1}\right)} = -\frac{V_2}{I_2} \cdot \left(\frac{N_1}{N_2}\right)^2 = R_L \left(\frac{N_1}{N_2}\right)^2
\]

**Hence, one can make** \( R_S = R_L \left(\frac{N_1}{N_2}\right)^2 \)

\( \Rightarrow P_{L_{\text{max}}} \) **can be achieved**
Phase relation between $I$ & $V$ in primary

1. Open circuit secondary

\[ I_1, I_2 = 0 \]

\[ V_1 = j\omega L_1 I_1 + j\omega M I_1 \]

\[ V_2 = j\omega L_2 I_2 + j\omega M I_1 \]

Hence transformer appears like $L_1, ! (V$ ahead of current by $\frac{\pi}{2}\!$)

2. Short circuit secondary

\[ V_1 = j\omega L_1 I_1 + j\omega M I_2 \]

\[ 0 = j\omega L_2 I_2 + j\omega M I_1 \Rightarrow I_2 = \frac{M}{L_2} (-I_1) \]

\[ V_1 = j\omega L_1 I_1 + j\omega M \frac{M}{L_2} (-I_1) = 0 ! \quad (M^2 = L_1 L_2) \]

3. In reality \( RW_2 \neq 0 \Rightarrow \left(\frac{N_1}{N_2}\right) \cdot RW_2 \) - resistive load
**Center Tap Rectifier (Full Wave)**

1. $V_{AC} > 0 \Rightarrow V_{S1} = V_{S2} > 0$
   - $D1$ - FB & $D2$ - RB
   - $I \approx \frac{V_0 - V_{DO}}{R_L}$

2. $V_{AC} < 0 \Rightarrow V_{S1} = V_{S2} < 0$
   - $I = \frac{V_0 - V_{DO}}{R_L}$

Assume $N_{21} = N_{22}$

$\Rightarrow V_{S1} = V_{S2}$

$\Rightarrow$ **Full Wave Rectifier**

$P_{IV} = -V_0 - (V_0 - V_{DO}) = -2V_0 + V_{DO}$